OPEN ACCESS
Journal of Animal Health and Production

Research Article

Effect of Gum Arabic on Overall Growth Performance, Visceral and Lymphoid Organs Along with Intestinal Histomorphology and Selected Pathogenic Bacteria of Broiler Chickens

Sajjad Khan*, Naila Chand, Abdul Hafeez, Nazir Ahmad

Department of Poultry Science, Faculty of Animal Husbandry and Veterinary Sciences, The University of Agriculture Peshawar, KPK, Pakistan.

Abstract | The aim of experiment was to find out the effect of different levels of gum arabic (GA) on overall growth performance, relative weight of visceral and lymphoid organs along with intestinal histomorphology and selected pathogenic bacteria in broiler chickens. A total of 160 day-old Ross chicks were assigned to four groups, containing 0, 0.5,1 and 1.5% GA along with basal feed for 42 days. A completely randomized design (CRD) was followed during statistical analysis while difference in means was calculated through Tukey's test. Results indicated that supplementation of GA at 1.5% significantly (P<0.05) improved feed intake, body weight gain, feed conversion ratio (FCR), European Production Efficiency Factor (EPEF) while no effect on livability of broiler chickens. High level (1.5%) of GA significantly (P<0.05) increased the relative weight of heart, liver and gizzard while no significant effect was observed on pancreas and lymphoid organs. Significantly high (P<0.05) villi height (VH), low crypt depth (CD) and high VH:CD was recorded at 1.5% GA in different parts of intestine. Similarly, count of *E. coli*, *Salmonella* and *C. perfringens* was significantly low in ileum, caecum and colon. It was concluded that supplementation of GA at 1.5% resulted in significantly (P<0.05) improved growth performance, visceral organs along with improved histomorphology and limited growth of pathogenic bacteria in broiler chickens.

Keywords | Gum arabic, Bursa, Thymus, *E. coli, Salmonella, C. perfringens*

Received | January 13, 2022; **Accepted** | January 25, 2021; **Published** | March 01, 2022
***Correspondence** | Sajjad Khan, Department of Poultry Science, Faculty of Animal Husbandry and Veterinary Sciences, The University of Agriculture Peshawar, KPK, Pakistan; **Email:** Sajjadkhan@aup.edu.pk
Citation | Khan S, Chand N, Hafeez A, Ahmad N (2022). Effect of gum arabic on overall growth performance, visceral and lymphoid organs along with intestinal histomorphology and selected pathogenic bacteria of broiler chickens. J. Anim. Health Prod. 10(1): 73-80.
DOI | http://dx.doi.org/10.17582/journal.jahp/2022/10.1.73.80
ISSN | 2308-2801

INTRODUCTION

Gum arabic (GA) is a natural dried juice obtained from acacia trees (Al-baadani et al., 2021), usually 2 to15 meters in height (Ahmed et al., 2020). It is an ancient and well known gum (Abdalla et al., 2015a) largely found in Sudan, Asia, Central and West Africa (Idris, 2017). Chemical composition of GA consists of main branched chain polysaccharides containing β-D-galactopyranosyl unite along with L-rhamnopyranosyl, L-arabinofuranosyl, D-glucopyranosyl uronic acid and D-galactopyranosyl side units (Aguado et al., 2021). From long ago, it has been used as emulsifier and stabilizer in food industry (Ayaz et al., 2017), cosmetic (Karlton-Senaye and Ibrahim, 2013) and pharmaceutical industry against many diseases (Ahmed, 2016). It is accepted as "safe" for human and animal use by the FAO (FAO, 2016) and is regularly used as prebiotic (Al-fadil et al., 2013) and food additive (Al-baadani et al., 2021). Broilers supplemented with GA indicated high body weight gain and heart weight (Tabidi and Ekram, 2015) along with high feed intake due to improved feed palatability (El-Khier et al., 2009). According to Houshmand et al. (2012) and Sang-Oh and Byung-Sung (2011) prebiotics, such as gum arabic, improves feed intake, weight gain and overall performance of poultry birds. High feed intake and improved FCR was also stated by Abd-Razig et al. (2010) and Al-fadil et al. (2013) in broiler chickens. Diet fortification with GA also improved the milk yield, litter size and lowered mortality in rabbits (Amber et al., 2020). It can not only reduce serum cholesterol and glucose levels (Abdalla et al., 2015a; b), but also lower the creatinine level (Musa et al., 2019), serum triglycerides (Abdelwahed et al., 2011; Abdalla et al., 2015a) and uric acid (Al-baadani et al., 2021).GA reduces liver fibrosis and necrosis (Hamid et al., 2021) along with improved absorption of calcium and kidney functions (Khojah, 2017; Ahmed et al., 2020) have also been reported in rats. Inside the poultry gut, GA is fermented to short-chain fatty-acids (SCFAs) which have a major balancing effect on structure and function of poultry gut (Al-baadani et al., 2021). These SCFAs can inhibit the attachment and colonization of pathogens through low pH and synergistically improving the growth of beneficial microbes (Adil et al., 2010) along with stimulation of epithelial and crypt cells production (Sobczak and kozlowski, 2015). GA can be utilized as nutrient by the poultry gut microflora and can indirectly result into high villus height and surface area which ultimately results in more nutrients absorption and high growth performance (Brufau et al., 2015). It can work as a powerful immune booster, slows down the growth of plasmodium (Ballal et al., 2011) along with a wide range of antimicrobial properties (Hu et al., 2016; Jaafar et al., 2016). The antimicrobial properties are due to the presences of saponins, saponin glycoside, hydrolysable tannins, volatile oils, flavonoid, triterpenoid, alkaloid and phenols (Ahmed, 2016). Different extracts of gum arabic have shown as vast antimicrobial activity against many bacteria and fungi (Patel and Goyal, 2015; Al-Alawi et al., 2018). So far, no documented work has been done over the use of local GA on broilers performance under semi-environmentally controlled sheds in Pakistan. So, purpose of the present experiment was to evaluate the effects of different levels of local variety of gum arabic on the overall growth performance, visceral and lymphoid organs weight along with intestinal histomorphology and selected pathogenic microbes in broiler chickens.

MATERIALS AND METHODS

Housing, feeding and management of broilers

Totally 160 day old Ross broiler chicks were indiscriminately assigned to four groups, each having four replicates and ten birds per replicate. Four different diets were provided to each of the four groups. Diet A was composed of basal diet with 0% GA (Table 1), while diet B, C and D were basal diets fortified with 0.5, 1 and 1.5% gum arabic. The temperature was kept at 95F during the first week of brooding, which was reduced at 5F per week up to 75F for the rest of the time. The relative humidity of the house was kept between 70 to 73%. Chicks were provided with *ad-libitum* water and feed during 42 days of experiment under similar managemantel and optimal environmental conditions.

Data was recorded on the following parameters:
Feed intake (FI)=feed offered-feed refused
Body weight gain (BWG)=final weight-weight at day 1st
Feed conversion ratio (FCR)=feed intake/weight gain
Livability (%) = (number of birds at the end / number of birds at the beginning) x 100
European Production Efficiency Factor (EPEF) = **(**Live weight of bird (Kg) x Livability %**)** / **(**Age of bird (days) x FCR**)**

Table 1: Chemical composition and ingredients of control feed (on fed basis)

Ingredients	Starter (day 1st to 21)	Finisher (day 22 to 42)
Fish meal	2.00	----
Wheat	2.00	5.00
Corn	49.25	51.66
Corn gluten	8.00	8.00
Fat (Animal source)	1.52	1.26
Soybean meal (45%)	34.18	31.07
Tricalcium phosphate	1.61	1.57
Choline-chloride (50%)	0.10	0.10
Limestone	0.60	0.70
DL-Methionine (88%)	0.24	0.14
Vitamin (Premix)	0.10	0.10
Mineral (Premix)	0.10	0.10
Salt	0.30	0.30
Calculated chemical composition		
Metabolic energy (Kcal/Kg)	3000	3200
Crude protein (%)	22.00	20.00
Average phosphorus (%)	0.45	0.40
Calcium (%)	1.00	0.90
Methionine + Cysteine (%)	0.95	0.80
Lysine (%)	1.25	1.11
Tryptophan (%)	0.28	0.25
Threonine (%)	0.86	0.78

Sampling and Measurements of internal visceral and lymphoid organs

At day-42, five broiler chicks close to the mean body weight were selected from each replicate and slaughtered. Heart, liver, gizzard, pancreas, bursa, spleen and thymus were quickly detached, weighed and finally relative weight (%) of each organ was calculated.

Intestinal histomorphology

On day 42, three birds per replicate close to the mean body weight were selected and slaughtered. Intestines were quickly separated from the birds and specimen of mid duodenum, jejunum and ileum was taken and washed away using normal saline. Each intestinal specimen was prepared for microscopy and morphological study as per the procedure described by Abdelqader et al. (2013). Simply, formalin (10%) was used for fixation, different graded ethanol for dehydration, xylene for clarification, paraffin for embedding, microtome for cutting five micron thick samples and finally Hematoxylin and Eosin (H&E) staining for microscopy. The measurement from villus tip to villus-crypt junction was taken as villus height while invagination between adjacent villi was taken as the crypt depth (Choe et al., 2012). A ten number of finely intact and structured crypt-villi unites were selected per intestinal sample and the averages were taken as mean villus height (VH) and crypt depth (CD) for each sample. Each sample was examined under microscope (Olympus CX41, Japan) and scanned with "Image Analyzer" (Nikon NIS-Element BR. Nikon Co., Tokyo, Japan).

Selected intestinal pathogenic bacteria

Three birds per replicate close to mean weight were selected for slaughtering through cutting the jugular vein. One gram content from ileum, caecum and colon was aseptically collected, homogenized and tenfold diluted with normal saline in sterile mixer bags. A serial tenfold dilution from 10^{-1} to 10^{-7} was performed at the laboratory and 100ul of each sample was applied on selective microbial media for *Escherichia coli* (MacConkey-Sorbitol Agar), *Salmonella* (SS Agar) and *C. perfringens* (Reinforced *Clostridial* agar) for appropriate duration, oxygen concentration and other culture requirements. A colony counter was used for counting bacterial colonies and finally the results were calculated and presented as log_{10}CFU/g fresh ileum, caecum and colon digesta.

Collection of gum arabic and ethical approval

Gum arabic was collected from the local surroundings and brought for confirmation to the Department of Horticulture, The University of Agriculture Peshawar. Ethical approval was granted by the departmental ethical committee before the initiation of the trail.

Statistics

IBM SPSS version 21.0 (SPSS Inc., Chicago, IL) software was used for statistical analysis following a completely randomized design. After analysis of variance, the results were subjected to Tukey's test for testing difference among the means. Data was presented as means and variation of data was shown as standard error of mean (SEM). The difference was considered as significant where P<0.05. Statistical model used; $Y_{ij}=\mu+\tau_j+\varepsilon_{ij}$

RESULTS

Overall growth performance

Results (Table 2) indicated a significantly (P<0.05) high feed intake in group D (3988.75g) followed by C (3902.50g) as compared to control A (3786.25g). Significantly high (P<0.05) body weight gain (BWG) was also recorded in group D (2362.50) and C (2285.00g) as compared to the control A (2182.50g). Similarly, significantly (P<0.05) improved FCR was recorded in group D (1.688) followed by group C (1.708) and B (1.719) as compared to control group A (1.735). Only a numerically improved livability (%) was recorded in group D (92.50), C (90.00) and B (87.50) without any significant difference (P>0.05) as compared to control A (85.00). Significantly high (P<0.05) EPEF was shown by D (308.17) and C (286.70) as compared to B (270.23) and control group A (254.74).

Visceral and lymphoid organs

Results (Table 3) indicated a significantly high (P<0.05) relative weight (%) of heart in group D (0.468) as compared to group C (0.464), B (0.464), and control group A (0.462). Significantly high (P<0.05) liver weight was also indicated by group D (2.244) as compared to C (2.225), B (2.217) and control group A (2.214). Similarly, group D (1.523) indicated significantly improved gizzard weight as compared to C (1.515), B (1.513) and control group A (1.510). Feeding different levels of GA indicated no significant (P>0.05) effects on relative weight of pancreas, bursa, spleen and thymus of all experimental broilers.

Intestinal histomorphology

Supplementation of GA at 1.5% in group D resulted (Table 4) a significant (P<0.05) improvement in villus height (VH) in duodenum (1865.00), jejunum (1255.50) and ileum (631.08) as compared to control group A. Similarly, dietary addition of gum at 1.5% in group D indicated significantly (P<0.05) low crypt depth (CD) in duodenum (223.58), jejunum (178.83) and ileum (133.75) as compared to control group. A significantly high (P<0.05) villus height to crypt depth ratio (VH:CD) was indicated by group D (1.5%) and C (1%) in duodenum (8.35 and 7.13), jejunum (7.03 and 6.00) and ileum (4.72 and 3.96) as compared to control group.

Selected intestinal pathogenic bacteria

Table 5 shows a significant (P<0.05) decrease in the *E. coli* count at 1.5% GA supplementation in ileum (log_{10} 4.049), caecum (6.839) and colon (5.391) as compared to control A group. A significantly low (P<0.05) count of *Salmonella* was also recorded in group D (1.5%) and C (1%) in ileum (2.018 and 2.034) caecum (2.213 and 2.228) and colon

Table 2: Effect of supplementation of different levels of gum arabic on FI, BWG, FCR, livability and EPEF of broilers at day 42.

GA %	FI (g)	BWG (g)	FCR	LI (%)	EPEF
A (0.0)	3786.25[c]	2182.50[c]	1.735[a]	85.00	254.74[b]
B (0.5)	3831.25[bc]	2228.75[c]	1.719[b]	87.50	270.23[b]
C (1.0)	3902.50[b]	2285.00[b]	1.708[c]	90.00	286.70[ab]
D (1.5)	3988.75[a]	2362.50[a]	1.688[d]	92.50	308.17[a]
SEM	21.53	18.05	0.004	1.25	6.23
P-Value	0.00	0.00	0.000	0.17	0.00

Means in the same column having different superscripts differ significantly (P<0.05). n=40 per group. Where FI=feed intake, BWG=body weight gain, FCR=feed conversion ratio, LI=livability, EPEP=European Production Efficiency Factor.

Table 3: Effect of supplementation of different levels of gum arabic on relative body weights (%) of visceral and lymphoid organs of broilers at day 42

GA %	Heart	Liver	Gizzard	Pancreas	Bursa	Spleen	Thymus
A (0.0)	0.462[b]	2.214[b]	1.510[b]	0.208	0.163	0.115	0.541
B (0.5)	0.464[b]	2.217[b]	1.513[b]	0.208	0.163	0.116	0.541
C (1.0)	0.464[b]	2.225[b]	1.515[b]	0.209	0.164	0.117	0.542
D (1.5)	0.468[a]	2.244[a]	1.523[a]	0.213	0.164	0.118	0.543
SEM	0.001	0.004	0.001	0.001	0.000	0.000	0.000
P-Value	0.000	0.001	0.002	0.068	0.389	0.117	0.081

Means in the same column having different superscripts differ significantly (P<0.05).
n=20 per group. Where GA=Gum arabic

Table 4: Effect of supplementation of different levels of gum arabic on intestinal histomorphology of broilers at day 42

Organs	Duodenum (µm)			Jejunum (µm)			Ileum (µm)		
GA %	VH	CD	VH:CD	VH	CD	VH:CD	VH	CD	VH:CD
A (0.0)	1795.00[b]	276.67[a]	6.56[c]	1208.17[b]	221.33[a]	5.52[c]	599.58[b]	166.00[a]	3.65[c]
B (0.5)	1806.67[b]	261.67[a]	6.92[bc]	1216.08[b]	210.83[a]	5.78[bc]	604.92[b]	158.25[a]	3.83[bc]
C (1.0)	1828.67[b]	257.50[a]	7.13[b]	1231.25[b]	205.83[a]	6.00[b]	610.67[b]	154.67[a]	3.96[b]
D (1.5)	1865.00[a]	223.58[b]	8.35[a]	1255.50[a]	178.83[b]	7.03[a]	631.08[a]	133.75[b]	4.72[a]
SEM	6.00	3.91	0.12	4.04	3.15	0.10	1.95	2.38	0.07
P-Value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Means in the same column having different superscripts differ significantly (P<0.05). n=12 per group. Where VH=Villus height, CD=Crypt depth, VH:CD=Villus height vs. Crypt depth

Table 5: Effect of supplementation of different levels of gum arabic on selected intestinal bacterial population Log_{10}/g wet digesta of broilers at day 42

Organs	Ileum			Caecum			Colon		
GA %	EC	SA	CP	EC	SA	CP	EC	SA	CP
A (0.0)	4.067[a]	2.110[a]	2.260[a]	6.856[a]	2.305[a]	2.352[a]	5.409[a]	2.255[a]	2.273[a]
B (0.5)	4.053[b]	2.096[a]	2.255[a]	6.842[b]	2.290[a]	2.347[a]	5.395[b]	2.241[a]	2.268[a]
C (1.0)	4.053[b]	2.034[b]	2.249[a]	6.842[b]	2.228[b]	2.341[a]	5.395[b]	2.179[b]	2.262[a]
D (1.5)	4.049[c]	2.018[b]	2.229[b]	6.839[c]	2.213[b]	2.321[b]	5.391[c]	2.164[b]	2.241[b]
SEM	0.001	0.006	0.002	0.001	0.006	0.002	0.001	0.006	0.002
P-Value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Means in the same column having different superscripts differ significantly (P<0.05).
n=12 per group. Where EC=*E. coli*, SA=*Salmonella*, CP=*C. perfringens*

(2.164 and 2.179) of the tested broilers. The lowest susceptibility was indicated by *C. perfringens* as only highest level of 1.5% supplemented GA indicated a significant (P<0.05) decrease in *C. perfringens* in ileum (2.229), caecum (2.321) and colon (2.241) as compared to all other groups.

DISCUSSION

Overall growth performance

Present results showed an improvement in overall physiological parameters of broiler chickens due to supplementation of gum arabic (GA). Similarly, El-Khier et al., (2009), Al-fadil et al. (2013) and Tabidi and Ekram (2015) reported that GA resulted in high feed intake (FI) and body weight gain (BWG) in broilers. According to Sang-Oh and Byung-Sung (2011), Houshmand et al. (2012) and Abdalla et al. (2015a), supplementation of prebiotic improved FI, BWG and overall performance of poultry birds. A significant increase in FI was also stated by Abd-Razig et al. (2010). In contrast, Midilli et al. (2008) reported that prebiotics have no significant effect on FI and BWG of broiler birds. It is suggested that the high level of GA enhanced the feed palatability and thus feed intake was improved. More than 85% of GA is composed of soluble fermentable fractions which improve the feed intake and palatability (El-Khier et al., 2009; Al-fadil et al., 2013). It can also improves the useful physiological effects such as reducing blood cholesterol and glucose along with laxative action and enhances mineral availability (Nasir et al., 2008). Similar to our findings, El-Ratel et al. (2019) stated that diet fortification with GA resulted high productivity in growing rabbits. In contrast to our findings, Al-fadil et al. (2013) and Tabidi and Ekram (2015) stated that GA has no significant effect on FCR of broiler chickens. Such differences may be due to difference in properties of GA as they are affected by rainfall, age of acacia tree, season of collection, storage type and duration (Tabidi and Ekram, 2015). Similar reports were submitted by Marinho et al. (2007) and Rayes et al. (2009) during their experimental work. Supplementation of GA indicated lowered mortality (Amber et al., 2020) and high European Production Efficiency Factor (EPEF) which ultimately leads to high profit. Prebiotic has the ability to improve the biological response and livability by increasing the resistance to diseases and lowering the mortality along with high nutrients availability and improved efficiency of poultry birds and livestock animals (Ganguly, 2013).

Visceral and lymphoid organs

Higher level of supplemented GA significantly improved the relative weight of visceral organs of experimental broiler chickens. Similar findings were reported by Tabidi and Ekram (2015). It is suggested that the increase in heart weight may be due to compensatory hypertrophy in response to high body weight gain and to efficiently pump the blood to high body mass. According to Pelicano et al. (2005), prebiotics have positive effects on visceral organs of broiler chickens. Our findings also justify the work of Tabidi and Ekram (2015) who stated that GA significantly improved the liver weight. This increase may be due to hyperplasia and hypertrophy of hepatocytes in response to high feed intake and weight gain. High body weight gain due to high feed intake triggers the metabolic processes of the liver hepatocytes to work harder and efficiently to meet the demands of fast growing body mass of broilers. This statement can be justified from the work of Hamid et al. (2021) who stated that GA has the potential to reduces the rate of liver fibrosis, necrosis and enhance the activity of antioxidant enzymes and ultimately improved liver functions. High level of GA also improved the relative weight of gizzard which may be due to compensatory hypertrophy and/or hyperplasia of gizzard's muscles in response to accumulate and compensate the high feed intake by broiler chickens. Similar increase in gizzard weight was reported by Tabidi and Ekram (2015). A linear improvement in weight of pancreas may be due to increased work load for the high level production of insulin and glucagon to meet the energy and carbohydrates demands of fast growing broiler chickens. Present results showed that increasing levels of gum arabic only numerically improved relative body weight (%) of bursa, spleen and thymus.

Intestinal histomorphology

Recent results indicated that GA has the potential to improve the intestinal architecture of broiler birds. These results are supported by the recent findings of Al-baadani et al. (2021) who stated that GA is fermented to SCFAs, which have a major part in normal structure and function of broiler gut. According to Brufau et al. (2015), supplementation of Duraio gum (0.1%) and cassia gum (0.1%) for 23 days resulted an increase in villus height and villus surface area, thus providing more area for nutrients absorption. Similar to our findings, Badia et al. (2012) reported improvement in villus heights while Yang et al. (2009) and Chee et al. (2010) reported no differences in villus heights. The present results indicated an inverse relation between increasing levels of GA and villus crypt depth. The high villus height along with low crypt depth provides vast surface area for nutrients absorption in duodenum, jejunum and ileum of broiler chicken. An increase in villus height is not directly due to prebiotic supplementation rather due to indirect effects of beneficial bacterial growth which ultimately stimulates the growth of intestinal villi (Baurhoo et al., 2007).

Selected intestinal pathogenic bacteria

Prebiotics have the ability to selectively modulate the gut bacteria and immunity of poultry birds (Sen et al., 2011;

Bozkurt et al., 2014). Similarly, prebiotics inhibit the growth of many gram negative bacteria through the synergistic growth and competitive exclusion mechanism of beneficial bacteria in poultry gut (Wang et al., 2016). In fast growing poultry birds like broilers, gut microbiota is like a nutritional "burden" (Dibner and Richards, 2005; Lan et al., 2005). Yang et al. (2009) mentioned that chickens grow 15% faster in pathogen free environment as compared to chickens exposed to contaminated environment. Baurhoo et al. (2007) stated that the prebiotics work as substrate for the metabolism and subsequent growth of beneficial microflora which are ultimately responsible for growth inhibition and colonization of pathogenic bacteria. The main approaches towards alternatives to antibiotic growth promoters are to inhibit the proliferation of harmful microbes and to modulate the normal flora so that growth performance, immune and health status are improved (Ravindran et al., 2006). Similar to our findings, Yang et al. (2009) mentioned that prebiotics reduced the *Salmonella* colonization in the gut. According to Yang et al. (2008), addition of β-Galactomannas resulted in high growth of Bifidobacteria and Lactobacilli in broiler intestine, which are responsible for reduction of pathogenic bacterial count through high mucus stimulation by goblet cells and competitive exclusion. Our results are justified by the early work of Biggs et al. (2007) who reported decreased count of *C. perfringens* in broiler birds supplemented with prebiotics. Al-fadil et al. (2013) reported that GA works as energy booster and reduces mortality by promoting the growth of beneficial microbiota, thus improves the immunity and safeguards the body to be less susceptible to poultry diseases. According to Jaafar et al. (2016), GA possesses antibacterial, antiviral, antioxidant and anti-inflammatory properties which are in agreement with our results.

CONCLUSIONS

It was concluded from the present results that supplementation of gum arabic (1.5%) has a positive effect on overall physiological status of broiler chicks along with improved intestinal histomorphology and restricted growth of selected pathogenic bacteria.

ACKNOWLEDGEMENTS

All the authors have significantly contributed in the research work and all the authors are in agreement to the content. It is further certified that this research paper has not been published/submitted in any journal.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

NOVELTY STATEMENT

People all over the world are getting more and more conscious about their health and shifting towards safe and healthy organic meat and other food stuff. So it is a quite novel work, especially in Pakistan, as gum arabic has been supplemented in broiler feed as alternative to antibiotic growth promoters (AGPs). Insha-Allah we are quite hopeful that it will generate new ways and ideas towards healthy organic poultry farming.

AUTHORS CONTRIBUTION

The experimental work was performed by Dr. Sajjad Khan under the supervision of Dr. Naila Chand and Co-supervisor Dr. Abdul Hafeez. Prof. Dr. Nazir Ahmad facilitated the work regarding feed formulation and GA supplementation in broiler feed.

REFERENCES

Abd-Razig NM, MK Sabahelkhier, OF Idris (2010). Effect of gum Arabic (Acacia senegal, L. Willd) on lipid profile and performance of laying hens. J. Appl. Biosci. 32:2002–2007.

Abdalla SA, KA Abdel-Atti, HEE Malik, BM. Dousa, KM Elamin. (2015a). Effect of dietary inclusion of gum arabic (Acacia senegal) on performance and blood chemistry of broiler chicks. Glob. J. Anim. Sci. Res. 3(2):305–310.

Abdalla SA, KA Abdel-Atti, HEE Malik, KM Elamin, BM Dousa (2015b). Effect of dietary inclusion of gum arabic (Acacia senegal) on layer hen performance, egg quality and egg cholesterol. Glob. J. Anim. Sci. Res. 3(3):636–640.

Abdelqader A, AR Al-Fataftah, G Das (2013). Effects of dietary Bacillus subtilis and inulin supplementation on performance, eggshell quality, intestinal morphology and microflora composition of laying hens in the late phase of production. Anim. Feed Sci. Technol. 179:103–111. https://doi.org/10.1016/j.anifeedsci.2012.11.003

Abdelwahed N, OF Idris, HI Seri (2011). Effect of feeding aum arabic on serum total and lipoproteins cholesterol in hypercholestrolemic rats. Assiut Vet. Med. J. 57:23–33. https://doi.org/10.21608/avmj.2011.172234

Adil S, T Banday, GA Bhat, MS Mir, M Rehman. (2010). Effect of dietary supplementation of organic acids on performance, intestinal histomorphology, and serum biochemistry of broiler chicken. Vet. Med. Int. ID 479485:1–7. https://doi.org/10.4061/2010/479485

Aguado R, BO Gomes, D Murtinho, AJM Valente (2021). Luminescent aqueous dispersion of lanthanide ions and gum arabic for coating. Mater. Chem. Appl.:181.

Ahmed AA, Fedail JS, Musa HH, Musa TH, Sifaldin AZ (2016). Gum Arabic supplementation improved antioxidant status and alters expression of oxidative stress gene in ovary of mice fed high fat diet. Middle East Fertil. Soc. J. 21 (2):101–108 https://doi.org/10.1016/j.mefs.2015.10.001.

Ahmed HE, SH Abdlrahman, SA Mohamed, MS Elbasheir, SM Elbadwi (2020). Evaluation of phytochemical composition and in-vivo antioxidant activity of gum arabic (Acacia senegal) aqueous extract in rats. J. Anim. Physiol. Nutr. Sci.

1(2):20–23. https://doi.org/10.46417/JAPN/2020.005

Al-Alawi SM, MA Hossain, AA Abusham (2018). Antimicrobial and cytotoxic comparative study of different extracts of Omani and Sudanese gum acacia. Beni-Suef Univ. J. Basic Appl. Sci. 7:22–26. https://doi.org/10.1016/j.bjbas.2017.10.007

Al-baadani HH, SI Al-Mufarrej, MA Al-Garadi, IA Alhidary, AA Al-Sagan, MM Azzam (2021). The use of gum arabic as a natural prebiotic in animals: A review. Anim. Feed Sci. Technol. 274(114894:1–12. https://doi.org/10.1016/j.anifeedsci.2021.114894

Al-fadil S, MA Mukhtar, HT Mohammad (2013). Response of broiler chicks to diets containing gum arabic as natural prebiotic. J. Curr. Res. Sci. 1(4):247–253.

Amber K, NA Badawy, WA Morsy, SM El-desoukey (2020). Milk yield, productive and reproductive performance of rabbit does fed different levels of arabic gum in diet. J. Sustain. Agric. Sci. 46(1):25–33.

Ayaz NO, Ramadan KS, Farid H (2017). Protective role and antioxidant activity of arabic gum against trichloroacetate-induced toxicity in liver of male rats. Indian J. Ani. Res. 51(2):303-309.

Badia R, Z Galliano, C Chevaleyre, R Lizardo, F Meurens, P Martínez, J Brufau, H Salmon (2012). Effect of Saccharomyces cerevisiae var. Boulardii and B-galactomannan oligosaccharide on porcine intestinal epithelial and dendritic cells challenged in vitro with Escherichia coli F4 (K88). Vet. Res. 43(4):1–11. https://doi.org/10.1186/1297-9716-43-4

Ballal A, D Bobbala, SM Qadri, M Föller, D Kempe, O Nasir, A Saeed, F Lang (2011). Anti-malarial effect of gum arabic. Malar. J. 10(139):1–7. https://doi.org/10.1039/9781849733106-00073

Baurhoo B, L Phillip, CA Ruiz-Feria (2007). Effects of purified lignin and mannan oligosaccharides on intestinal integrity and microbial populations in the ceca and litter of broiler chickens. Poult. Sci. 86:1070–1078. https://doi.org/10.1093/ps/86.6.1070

Biggs P, CM Parsons, GC Fahey (2007). The effects of several oligosaccharides on growth performance, nutrient digestibilities and cecal microbial populations in young chicks. Poult. Sci. 86:2327–2336. https://doi.org/10.3382/ps.2007-00427

Bozkurt M, N Aysul, K Küçükyilmaz, S Aypak, G Ege, AU Çatli, H Aksit, F Çöven, K Seyrek, M Çınar (2014). Efficacy of in-feed preparations of an anticoccidial, multienzyme, prebiotic, probiotic and herbal essential oil mixture in healthy and Eimeria spp. -infected broilers. Poult. Sci. 93:389–399. https://doi.org/10.3382/ps.2013-03368

Brufau MT, R Martín-Venegas, A. M. Guerrero-Zamora, A. M. Pérez-Vendrell, B. Vilà, J. Brufau, and R. Ferrer. 2015. Dietary β-galactomannans have beneficial effects on the intestinal morphology of chickens challenged with Salmonella enterica serovar Enteritidis. J. Anim. Sci. 93:238–246. https://doi.org/10.2527/jas.2014-7219

Chaubal, R., A. Tambe, S. Biswas, S. Rojatkar, V. Deshpande, and N. Deshpande. 2006. Isolation of new straight chain compounds from Acacia nilotica. Indian J. Chem. 45(B):1231–1233. https://doi.org/10.1002/chin.200639218

Chee SH, PA Iji, M Choct, LL Mikkelsen, A. Kocher (2010). Functional interactions of manno-oligosaccharides with dietary threonine in chicken gastrointestinal tract . I. Growth performance and mucin dynamics. Br. Poult. Sci. 51(5):658–666. https://doi.org/10.1080/00071668.2010.517251

Choe DW, Loh TC, Foo HL, Hair-Bejo M, Awis QS (2012). Egg production, faecal pH and microbial population, small intestine morphology, and plasma and yolk cholesterol in laying hens given liquid metabolites produced by Lactobacillus plantarum strains. Br. Poult. Sci. 53:106–115.

Dibner JJ, JD Richards (2005). Antibiotic growth promoters in agriculture: History and mode of action. Poult. Sci. 84:634–643. https://doi.org/10.1093/ps/84.4.634

El-Khier MKS, KEA Ishag, A EL Gasim, A Yagoub, AA Abu Baker (2009). Supplementing laying hen diet with gum arabic (Acacia senegal): Effect on egg production, shell thickenss and yolk content of cholesterol, calcium and phosphorus. Asian J. Poult. Sci. 3(1):9–14. https://doi.org/10.3923/ajpsaj.2009.9.14

El-Ratel IT, RF SA Ismail, SF Fouda (2019). Productive performance, carcass traits, lipid profile, antioxidants and immunity of growing rabbits treated with gum arabic under Egyptian summer condition. Egypt. J. Nutr. Feed. 22(2):383–394. https://doi.org/10.21608/ejnf.2019.79436

FAO (2016). Probiotics in animal nutrition-Production, impact and regulation by Yada S. Bajagai, Athol V. Klieve, Peter J. Dart and Wayne L.Bryden. Editor Harinder P.S. Makkar. FAO Anim. Prod. Heal. Pap. No. 179. R:1–108.

Ganguly S (2013). Supplementation of prebiotics, probiotics and acids on immunity in poultry feed: a brief review. Worlds. Poult. Sci. J. 69:639–648. https://doi.org/10.1017/S0043933913000640

Hamid M, Y Abdulrahim, A Abdelnasir, KM Mohammedsalih, NA Omer, JA Abaker, H. M. A. Hejair, T. Elkhier TN Mahmoud, HB Zolain (2021). Dietary gum arabic alleviates carbon tetrachloride induced liver fibrosis in Wistar rats. Asian J. Res. Anim. Vet. Sci. 8(3):1–12.

Houshmand M, K Azhar, I Zulkifli, MH Bejo, A Kamyab (2012). Effects of prebiotic, protein level and stocking density on performance, immunity and stress indicators of broilers. Poult. Sci. 91:393–401. https://doi.org/10.3382/ps.2010-01050

Hu Q, Gerhard H, Upadhyaya I, Venkitanarayanan K, Luo Y (2016). Antimicrobial eugenol nano emulsion prepared by gum arabic and lecithinand evaluation of drying technologies. Int. J. Biol. Macromol. 87:130–140.

Idris OHM (2017). What is gum Arabic? an overview. Int. J. Sudan Res. 7(1):1–14.

Jaafar SF, AA Abdelkareem, HM Hassan, I Elsadik, Amal Z Sifaldin, HM Taha (2016). Gum arabic improves semen quality and oxidative stress capacity in alloxan induced diabetes rats. Asi. Paci. J. Repro. 5:434–441.

Karlton-Senaye BD, Ibrahim S.A (2013). Agro Food Industry Hi-Tech. 24:10–14.

Khojah EY (2017). Biological effects of low protein diet with gum arabic on rats chronic kidney disease. Adv. Environ. Biol. 11(4):60-69.

Lan Y, MWA Verstegen, S Tamminga, BA Williams (2005). The role of the commensal gut microbial community in broiler chickens. Worlds. Poult. Sci. J. 61(1):95–104. https://doi.org/10.1079/WPS200445

Marinho MC, MM Lordelo, LF Cunha, JPB Freire (2007). Microbial activity in the gut of piglets: I. Effect of prebiotic and probiotic supplementation. Livest. Sci. 108:236–239. https://doi.org/10.1016/j.livsci.2007.01.081

Midilli M, M Alp, N Kocabagh, OH Muglah, N Turan, H Yilmaz, S Cakir (2008). Effects of dietary probiotic and prebiotic supplementation on growth performance and serum IgG concentration of broilers. S. Afr. J. Anim. Sci.

38:21–27. https://doi.org/10.4314/sajas.v38i1.4104

Morales-Lopez R, E Auclair, F García, E Esteve-Garcia, J Brufau (2009). Use of yeast cell wall; B-1 3/1, 6-glucans; and mannoproteins in broiler chicken diets. Poult. Sci. 88:601–607. https://doi.org/10.3382/ps.2008-00298

Musa BB, Y Duan, H Khawar, Q Sun, Z Ren, EM Mohamed Abdalla, IHR Abbasi, X. Yang (2019). Bacillus subtilis B21 and Bacillus licheniformis B26 improve intestinal health and performance of broiler chickens with Clostridium perfringens-induced necrotic enteritis. J. Anim. Physiol. Anim. Nutr. (Berl). 103:1039–1049. https://doi.org/10.1111/jpn.13082

Nasir O, F Artunc, A Saeed, MA Kambal, H Kalbacher, D Sandulache, KM Boini, N Jahovic, F Lang (2008). Effects of gum arabic (Acacia senegal) on water and electrolyte balance in healthy mice. J. Ren. Nutr. 18(2):230–238. https://doi.org/10.1053/j.jrn.2007.08.004

Patel S, A Goyal (2015). Applications of natural polymer gum arabac: A review. Int. J. Food Prop. 18(5):986–998. https://doi.org/10.1002/app.42281

Pelicano E, P Souza, H Souza, A Oba, M Boiago, N Zeola, A Scatolini, V Bertanha, T Lima (2005). Carcass and cut yields and meat qualitative traits of broilers fed diets containing probiotics and prebiotics. Brazilian J. Poult. Sci. 7(3):169–175. https://doi.org/10.1590/S1516-635X2005000300006

Ravindran V, DV Thomas, DG Thomas, PCH Morel (2006). Performance and welfare of broilers as affected by stocking density and zinc bacitracin supplementation. Anim. Sci. J. 77:110–116. https://doi.org/10.1111/j.1740-0929.2006.00327.x

Rayes N, D Seehofer, P Neuhaus (2009). Prebiotics, probiotics, synbiotics in surgery-are they only trendy, truly effective or even dangerous? Langenbecks Arch. Surg. 394:547–555. https://doi.org/10.1007/s00423-008-0445-9

Sang-Oh P, P Byung-Sung. (2011). Effect of dietary microencapsulated-inuline on carcass characteristics and growth performance in broiler chickens. J. Anim. Vet. Adv. 10(10):1342–1349. https://doi.org/10.3923/javaa.2011.1342.1349

Sen S, SL Ingale, JS Kim, KH Kim, YW Kim, C Khong, JD Lohakare, EK Kim, HS Kim, IK Kwon, BJ Chae (2011). Effect of supplementation of Bacillus subtilis LS 1-2 grown on citrus-juice waste and corn- soybean meal substrate on growth performance, nutrient retention, caecal microbiology and small intestine morphology of broilers. Asian-Aust. J. Anim. Sci. 24(8):1120–1127. https://doi.org/10.5713/ajas.2011.10443

Sobczak A, K Kozlowski (2015). The effect of a probiotic preparation containing Bacillus subtilis ATCCPTA-6737 on egg production and physiological parameters of laying hens. Ann. Anim. Sci. 15:711–723.

Tabidi MH, KA Ekram (2015). Effect of feeding gum arabic with or without commercial xylem enzyme 500 on the performance of brioler chicks. World J. Pharm. Pharm. Sci. 4(9):1863–1872.

Wang X, YZ Farnell, ED Peebles, AS Kiess, KGS Wamsley, W Zhai (2016). Effects of prebiotics, probiotics and their combination on growth performance, small intestine morphology and resident Lactobacillus of male broilers. Poult. Sci. 95:1332–1340. https://doi.org/10.3382/ps/pew030

Yang Y, PA Iji, M Choct (2009). Dietary modulation of gut microflora in broiler chickens: a review of the role of six kinds of alternatives to in-feed antibiotics. Worlds. Poult. Sci. J. 65:97–114. https://doi.org/10.1017/S0043933909000087

Yang Y, PA Iji, A Kocher, LL Mikkelsen, M Choct (2008). Effects of dietary mannanoligosaccharide on growth performance, nutrient digestibility and gut development of broilers given different cereal-based diets. J. Anim. Physiol. Anim. Nutr. (Berl). 92:650–659. https://doi.org/10.1111/j.1439-0396.2007.00761.x